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EFFECT OF INCORPORATION OF CELLULOSE INDUSTRIAL RESIDUE IN CONCRETE MATRIX

Elvis .M. Mbadike[1†] --- Okafor F.O[2] --- Agunwamba J.C.[3]
[1]*Lecturer, Department of Civil Engineering, Michael Okpara University of Agriculture, Umudike, Umuahia. Abia State, Nigeria*
[2,3]*Professors of Civil Engineering, University of Nigeria, Nsukka, Nigeria*

ABSTRACT

The goal of producing concrete that provides long term durability with regard to properties such as strength and reduced susceptibility to alkali-silica reactions has led to the development of several high performance materials. In this research work, the effect of cellulose industrial residue in concrete matrix was investigated. A mix proportion of 1:1:6:3.2 with water-cement ratio of 0.47 were used. The percentage replacement of Ordinary Portland Cement (OPC) with cellulose industrial residue (CIR) is 0%, 5%, 10%, 20%, 30% and 40%. Concrete cubes of 150mm x 150mm x 150mm of OPC/CIR were cast and cured at 3,7,28,60 and 90 days respectively. At the end of each hydration period, the three concrete cubes for each hydration period were crushed and their average compressive strength recorded. A total of ninety (90) concrete cubes was cast. The result of the compressive strength test for 5-40% replacement of cement with cellulose industrial residue ranges from 13.02-32.81 N/mm² as against 25.60-42.08 for the controi test. Similarly, the setting time of 5-40% replacement of cement with CIR ranges from 61-118mins for the initial setting time and 620-836mins for the final setting time as against 52mins and 950mins for the initial and final setting time respectively for the control test (0% replacement). The result of the slump test for 5-40% replacement of cement with CIR ranges from 12-53mm as against 6mm for the control test. The major aim of this research work is to determine the effect of cellulose industrial residue when used at a certain replacement level of cement in concrete matrix.

Keywords: Setting time, Compressive strength, Cellulose, Industrial residue, Slump, Curing, Cube, Ordinary Portland Cement, Pozzolan and concrete.

Contribution/ Originality

The material (Cellulose industrial residue) can be used as a pozzolan in concrete production. This research work is original and have not been carried out anywhere.

† Corresponding author

1. INTRODUCTION

The incorporation of waste in concrete manufacture may provide a satisfactory solution to the problems posed by waste management [1]. The building sector uses large quantities of natural materials, hence its capacity to recycle and upgrade waste is considerable [2]. Certain industrial byproducts have been used for a number of years as cement or concrete components [3]. Other waste products may also be recycled and upgrade in concrete [4].

However, the new material thus formed must be usable as a building material and in particular have the necessary performance characteristics to satisfy the specifications determined by its application [5]. In addition, it should be inoffensive with regards to health and the environment. Finally, the incorporation of the waste should not impair concrete durability. Traditional assessment methods must therefore be adopted to evaluate these new materials [6]. This study contributes to the development of a methodology for assessing concrete manufactured from waste. The methodology is based on the study of concrete containing experimental waste (cellulose industrial residue). The cellulose industrial residue is considered as experimental waste because of, in particular, its high content of soluble salt [7]. The durability and the environmental impact of concrete are closely connected to its transport properties which control the kinetics of the penetration of water and aggressive agents into concrete [8]. The movement of chemical species within the material and the leaching of certain chemicals are also closely linked to concrete diffusivity. [9]. The characteristics of concrete containing increasing levels of cellulose industrial residue was studied to identify the effect of the residue on concrete produced with it. Finally, alternative ways for disposal of wastes should be attempted and research into the economical reuse of several wastes appeared in the recent years including the incorporation in day based products [10-14].

2. METHODOLOGY

Concrete mixtures with six levels of cellulose industrial residue (CIR) ranging from 5-40% and concrete mixtures with no CIR were investigated to determine their effect on compressive strength. The mixture were labeled M0, M5, M10, M20, M30 and M40 with the different CIR replacement percentages represented by the final digits in the label. The mixtures were proportioned for a target cube strength of 43N/mm^2 and had a cementitious material content of 240kg/m^3, a fine aggregate content of 627kg/m^3, a coarse aggregate content of 1273kg/m^3, and a water cementitious ratio of 0.47.The cellulose industrial residue (CIR) in this research was obtained from Aluminum Extrusion Industry (ALEX) Inyishi in Ikeduru LGA of Imo State. The fine aggregate used was clean river sand, free from deleterious substances with a specific gravity of 2.62 and a bulk density of 1533kg/m^3. The coarse aggregate was obtained from a local supplier with a maximum size of 20mm, specific gravity of 2.65 and bulk density of 1467kg/m^3. Both aggregates conform to British Standard Institution BS877 [15] and British Standard Institution BS 3797 [16] respectively for coarse and fine aggregates.

The cement used to be Ordinary Portland Cement (Dangote) which conforms to BS12.

Tests to determine setting time, slump and compressive strength were carried out in this study. For setting time and compressive strength tests, Cellulose Industrial Residue was used to replace 0 to 40% of cement by weight. For the compressive strength tests, 150mm (6in) cube specimen were cast and cured in water at room temperature in the laboratory for 3,7,28,60 and 90 days. At the end of each hydration period, three specimens for each were tested for compressive strength and the average recorded.

The slump test was carried out using 300x200x100mm standard slump cone.

The setting time was determined in the laboratory using Vicat apparatus. For the control test (0% replacement), 200g of cement was used with 94g of water during the experiment to form a cement paste. The paste was then placed inside the Vicat mould and final placed on the Vicat apparatus. Before the piacement of the paste on the apparatus, the initial setting pin was fixed on the apparatus for the initial setting time. The apparatus is calibrated in millimeters. For the initial setting time, the initial setting pin was dropped on the paste to 5 ± 1mm calibration mark on the apparatus. The initial setting time was then recorded starting from the time water was added to cement to the time the dropping of the pin was 5 ± 1mm mark on the apparatus [17, 18]. Similarly, the final setting time was recorded using the final setting pin. The final setting time was taken when only the inner pin makes a mark on the paste when allowed to drop freely. The final setting time was then recorded starting from the time water was added to the cement to the time the inner pin of the final setting pin makes a mark on the paste.The experiment was repeated with 5%, 10%, 20%, 30% and 40% replacement of cement with cellulose industrial residue.

3. RESULTS AND DISCUSSION

Table 1 shows the physical and chemical composition of cellulose industrial residues. The result shows that the percentage humidity, total carbon, and total solid content of cellulose industrial residue is 85%, 46% and 15% respectively. The percentage fibre content is 0%. The percentage content of calcium is 3.9%. The setting times of OPC/Cellulose industrial residue paste are important for practical application of the material. This was determined using the Vicat method [19] and the result is shown in table 2. The setting times increases. The initial and final setting time of the control test (0% replacement) is 52mins and 590mins respectively while 5-40% replacement of cement with cellulose industrial residue ranges from 61-118mins and 620-836mins for the initial and final setting time respectively. Thus, cellulose industrial residue defers the hydration of the paste and extends the setting time. This shows that cellulose industrial residue can be used as a retarder and thus, is a good material for hot weather concreting, like aluminum waste [20].

Table 3 shows the result of slump test. The highest slump test result obtained for 0%, 5%, 10%, 20%, 30% and 40% replacement of cement with cellulose industrial residue was 6mm, 18mm, 22mm, 30mm and 53mm respectively. The result of the slump test increased as the percentage replacement of cement with cellulose industrial residue increased. This indicates a decrease in the strength of concrete produced as the percentage replacement of cement with cellulose industrial residue increased. V Table 4 shows the compressive strength of OPC/CIR concrete mixes with different CIR contents and with different hydration period. The result shows that there is an increase in strength of concrete produced as hydration period increased. The strength of concrete decreased as the percentage replacement level of cellulose industrial residue increased. As the hydration period increased, the difference in strength between the control mix (0% CIR) and the mixes for 5-40% replacement is reduced. This process of strength development is expected to continue with hydration period until completion of hydration of cement – Cellulose industrial residue mixture [3]. These results confirm those obtained by other researchers using similar materials [9, 20, 21].

Table-1. Physical and Chemical Properties of Cellulose Industrial Residue

Property	Cellulose Industrial Residue
Humidity(%)	85
Total carbon(%)	46
Total solids(%)	15
Fibre content(%)	None
Ca(%)	3.9
Mg(%)	0.21
Na(%)	0.77
K(%)	0.28
Fe(%)	0.43
Ni(mg/kg)	31.3
Cu(mg/kg)	27.3
Zn(mg/kg)	71.4
Pb(mg/kg)	22.3

Table-2. Initial and final setting time of OPC/cellulose industrial residue paste.

% cement replacement	Initial setting time (mins)	Final setting time (mins)
0	52	590
5	61	620
10	76	665
20	89	679
30	94	752
40	118	836

Table-3. Result of Slump Test (mm)

Mix Nos	3d	7d	28d	60d	90d
Mo	2.5	4.0	50	4.5	6.0
M5	6.5	6.0	12.0	10.0	9.0
M10	5.0	10.0	14.5	18.0	16.5
M20	18.0	15.0	19.0	19.5	22.0
M30	13.0	30	44.0	53.0	51.0
M40	32.0	38.0	44.0	53.0	51.0

Where d = days

Table-4. Result of Compressive Strength Test (N/mm^2)

Mix Nos	Cellulose Industrial Residue(%)	3d	7d	28d	60d	90d
Mo	0	25.60	27.41	30.55	38.52	42.08
M5	5	20.81	23.57	26.95	28.83	32.81
M10	10	17.82	21.55	23.72	26.68	29.80
M20	20	16.07	20.44	23.05	25.27	27.69
M30	30	15.08	19.75	21.98	23.78	26.27
M40	40	13.02	17.90	20.97	22.90	25.13

Where d = days

4. CONCLUSION

The conclusion of the study can be summarized as follows:

a. The incorporation of cellulose industrial residue in concrete matrix will reduce the strength of concrete produced.

b. The setting time of cement/cellulose industrial residue increases as the percentage replacement level of cement with the residue increases.

c. The strength development in the concrete produced increases with the increase in the hydration period.

d. Cellulose industrial residue can be used as an admixture (retarder) in concrete production.

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Appendix

APPENDIX-1.

Table-3a. Result of Slump Test (mm)

% cement Replacement	Slump (mm)
0	6
5	12
10	18
20	22
30	30
40	53

APPENDIX-2.

Table-4a. Result of compressive strength obtained with 0% replacement of cement with cellulose industrial residue.

Cube size (mm)	Age of cube (days)	Test load (KN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
150x150x150	3	580	25.78	
150x150x150	3	552	24.53	25.60
150x150x150	3	596	26.49	
150x150x150	7	567	25.16	
150x150x150	7	655	29.11	27.41
150x150x150	7	628	27.91	
150x150x150	28	700	31.11	
150x150x150	28	699	31.07	30.55
150x150x150	28	663	29.47	
150x150x150	60	814	36.18	
150x150x150	60	796	35.38	38.52
150x150x150	60	990	44.00	
150x150x150	90	1001	44.49	
150x150x150	90	888	39.47	42.08
150x150x150	90	951	42.27	

APPENDIX-3.

Table-4b. Result of compressive strength obtained with 5% replacement of cement with cellulose industrial residue

Cube size (mm)	Age of cube (days)	Test load (KN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
150x150x150	3	520	23.11	
150x150x150	3	460	20.44	20.81
150x150x150	3	425	18.89	
150x150x150	7	580	25.78	
150x150x150	7	521	23.16	23.57
150x150x150	7	490	21.78	
150x150x150	28	612	27.20	
150x150x150	28	641	28.49	26.95
150x150x150	28	566	25.16	

150x150x150	60	706	31.38	
150x150x150	60	660	29.33	28.83
150x150x150	60	580	25.78	
150x150x150	90	700	31.11	
150x150x150	90	790	35.11	32.81
150x150x150	90	725	32.22	

APPENDIX-4.

Table-4c. Result of compressive strength obtained with 10% replacement of cement with cellulose industrial residue.

Cube size (mm)	Age of cube (days)	Test load (KN)	Compressive strength (N/mm²)	Average compressive strength (N/mm²)
150x150x150	3	360	16.00	
150x150x150	3	450	20.00	17.82
150x150x150	3	393	17.47	
150x150x150	7	455	20.22	
150x150x150	7	491	21.82	21.55
150x150x150	7	509	22.62	
150x150x150	28	580	25.78	
150x150x150	28	520	23.11	23.72
150x150x150	28	501	22.27	
150x150x150	60	596	26.49	
150x150x150	60	633	28.13	26.68
150x150x150	60	572	25.42	
150x150x150	90	660	29.33	
150x150x150	90	622	27.64	29.80
150x150x150	90	730	32.44	

APPENDIX-5.

Table-4d. Result of compressive strength obtained with 20% replacement of cement with cellulose industrial residue.

Cube size (mm)	Age of cube (days)	Test load (KN)	Compressive strength (N/mm²)	Average compressive strength (N/mm²)
150x150x150	3	415	18.44	
150x150x150	3	310	13.78	16.07
150x150x150	3	360	16.00	
150x150x150	7	426	18.93	
150x150x150	7	463	20.58	20.44
150x150x150	7	491	21.82	
150x150x150	28	560	24.89	
150x150x150	28	515	22.89	23.05
150x150x150	28	481	21.38	
150x150x150	60	550	24.44	
150x150x150	60	617	27.42	25.27
150x150x150	60	539	23.96	
150x150x150	90	644	28.62	
150x150x150	90	625	27.78	27.69
150x150x150	90	600	26.67	

APPENDIX-6.

Table-4e. Result of compressive strength obtained with 30% replacement of cement with cellulose industrial residue.

Cube size (mm)	Age of cube (days)	Test load (KN)	Compressive strength (N/mm²)	Average compressive strength (N/mm²)
150x150x150	3	320	14.22	
150x150x150	3	400	17.78	15.08
150x150x150	3	298	13.24	
150x150x150	7	410	18.22	
150x150x150	7	450	20.00	19.75
150x150x150	7	473	21.02	
150x150x150	28	545	24.22	
150x150x150	28	500	22.22	21.98
150x150x150	28	439	19.51	
150x150x150	60	500	22.22	
150x150x150	60	586	26.04	23.78
150x150x150	60	519	23.07	
150x150x150	90	622	27.64	
150x150x150	90	598	26.58	26.27
150x150x150	90	553	24.58	

APPENDIX-7.

Table-4f. Result of compressive strength obtained with 40% replacement of cement with cellulose industrial residue.

Cube size (mm)	Age of cube (days)	Test load (KN)	Compressive strength (N/mm²)	Average compressive strength (N/mm²)
150x150x150	3	251	11.16	
150x150x150	3	308	13.69	3.11
150x150x150	3	320	14.22	13.02
150x150x150	7	342	15.20	
150x150x150	7	402	17.87	4.10
150x150x150	7	464	20.62	17.90
150x150x150	28	510	22.68	
150x150x150	28	487	21.64	4.83
150x150x150	28	418	18.58	20.97
150x150x150	60	497	22.09	
150x150x150	60	511	22.71	6.52
150x150x150	60	538	23.91	22.90
150x150x150	90	594	26.40	
150x150x150	90	603	26.80	8.55
150x150x150	90	499	22.18	25.13